STRENGTH OF MATERIALS
Elastic Modulus of Wires

Objective

The objective of this lab exercise is to determine the elastic modulus of a given material and to further demonstrate that the elastic modulus is a geometry independent material property.

Theory

Stress, like pressure, is a term used in strength of materials to describe the intensity of a force - the quantity of force that acts on a unit of area. To say, for instance, that a particular piece of steel can withstand a tensile stress of 60,000 psi simply means that every square inch of cross-sectional area can support 60,000 lb. in tension. The inference in the preceding statement is that every portion of the area supports an equal share of the load; the stress, in other words, is uniform.

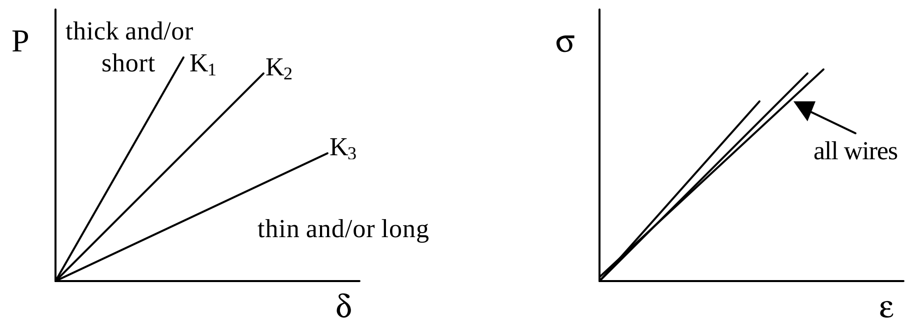
When a system of loads is applied to a machine component or structural element, individual points of the body generally move. This movement of a point with respect to some convenient reference system of axes is a vector quantity known as displacement. When displacements are induced by an applied load, individual points of the body move relative to each other; therefore, the size and/or shape of the body is altered. The change in any dimension associated with these load displacements is known as deformation. Strain is a quantity used to provide a measure of the intensity of deformation (deformation per unit length) just as stress is used to provide a measure of the intensity of an internal force (force per unit area). Normal strain is used to provide a measure of the elongation or contraction of an arbitrary line segment in a body during deformation.

Experimental work by Robert Hooke demonstrated that stress and strain were related by a simple linear relationship if stresses were low enough that no permanent damage was done to the material. This statement is expressed mathematically as:

$$\sigma = E\varepsilon \qquad (1)$$

where stress (σ) is typically in units of lb/in^2 or N/m^2 and strain (ε) is in units of in/in or m/m. The quantity E is called the elastic modulus and has units of lb/in^2 or N/m^2. It is a loading rate independent material property for many structural materials.

If axial loads are applied to wires of different sizes and axial elongations are measured, different load displacement relationships result as shown in Figure 1(a). Short wires with large diameters are stiff and long wires with small diameters are flexible. Stiffness of wires is often denoted by the letter K and represents the slope of the load-elongation records shown in Figure 1(a). Converting load-elongation records to stress-strain plots causes all data for a particular material to fall on a single line with slope E as shown in Figure 1(b). The demonstration of this experimental observation is one of the objectives of the laboratory.



(a) (b)

Figure 1 – (a) Load (P) versus elongation (d) and (b) stress (s) versus strain (e) for three wires of differing geometries.

Mathematically the elastic modulus can be related to the measured load (P) and elongation (δ) data by starting with Eq.1 and substituting as follows:

$$\frac{P}{A} = \boldsymbol{s} = E\boldsymbol{e} = E\frac{\boldsymbol{d}}{L} \qquad (2)$$

$$E = \frac{PL}{\boldsymbol{d}A} \qquad (3)$$

where L and A are the initial length and cross sectional area, respectively. The quantity P/δ represents the stiffness of each individual wire (K_i) so E can be calculated from

$$E = K_i\left(\frac{L}{A}\right) \qquad (4)$$

for wires i = 1,2,3,.... In this laboratory, the stiffness of two individual wires will be measured and related to E using Eq. 4. The resulting experimental elastic moduli are to be compared to the handbook value of $16\text{x}10^6$ psi for this material.

One additional case is included in which the load is applied to two wires held in parallel so that the applied load is carried by the two wires in combination. The same displacement is applied to each wire, and the stiffness for the entire two-wire system is to be measured experimentally. What area should be used in Eq. 4?

Experimental Procedure

Measure and record on the data sheet the apparatus number, wire diameter and length (see Figure 2).

- Thin wire: use the notch for a 3-to-1 lever action and use a pre-load of one pound.
- Thick wire: use the notch for a 4-to-1 lever action and use a pre-load of one pound.
- Two wire system: use the notch for a 4-to-1 lever action and use a pre-load of two pounds.

Record the elongation on the datasheet in 1-lb increments. Do not exceed the amount of load provided with a given apparatus.

Report

Use a spreadsheet/graphing program to obtain the following:

(1) graphs of load versus deformation for all three configurations on a single graph, plotting the load and unload data points for each configuration as a single data set

(2) obtain the stiffness (slope K), y-intercept, and correlation factor for each load vs. deformation plot

(3) create a plot of stress versus strain for all data sets on a single graph

(4) obtain the elastic modulus demonstrated by each set of data.

All parts of the laboratory report must be completed as directed by the instructor and in accordance with guidelines provided.

Raw Data:

Specimen	Thin Wire	Specimen	Thick Wire	Specimen	Double wires
Diameter		Diameter		Diameter	
Length		Length		Length	
Apparatus No.		Apparatus No.		Apparatus No.	
Load Ratio	3:1	Load Ratio	4:1	Load Ratio	4:1

Load (lb)	Deflection(in)	Load (lb)	Deflection(in)	Load (lb)	Deflection(in)

Computed Data:

	Thin Wire	Thick Wire	Double Wire
Area (in)			
Least Squares Fit:			
Slope K			
y-intercept			
Correlation Factor			
E (psi)			
% error compared to handbook value			

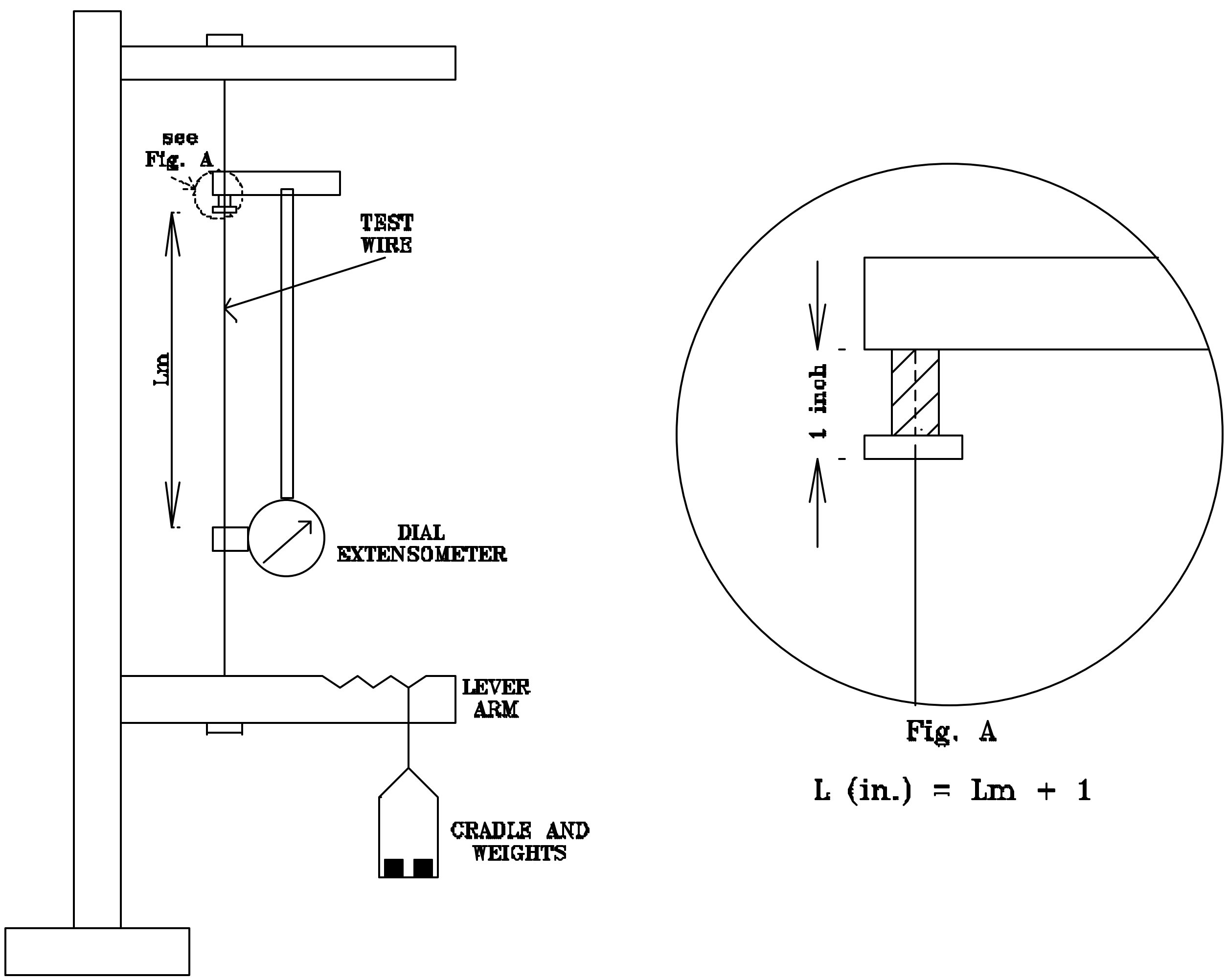


Figure 2 – Schematic of test apparatus and measurement of total initial length L.